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Impact of Anthropogenic Pressures on Forest Structure and Species Composition of Moist Deciduous Forest in Thithimathi Range of Western Ghats, India

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Abstract

The present investigation involves studying the impact of human interference on species composition, forest structure and regeneration pattern in moist deciduous forest. Six study areas that are proximal and distant to the settlements (hamlets) in the buffer zone were selected. Anthropogenic pressure is a common phenomenon in the developing countries where the population growth rate is high. The results revealed that the species richness, Shannon's diversity index, basal area and density were less in the areas close to the settlements compared to the areas away from the settlements. The average value index (AVI) was adopted and the disturbance parameters were classified into major, moderate and minor categories having the AVI value ≥ 1.55, 1 to 1.54 and ≤1 respectively. Lopping, cut stumps, grazing, litter collection, soil removal, domestic animal's dung and canopy opening showed significant variation between first transect and the last transect. Cumulative disturbance index (CDI) and the regeneration density of population showed a negative correlation. Increased value of CDI has shown a decreased regeneration status of tree species (R^2 = 0.775). The trend line showed higher density of regenerating individuals in low and medium level of CDI and decreased drastically with increasing in CDI. The total number of regenerated seedlings in first transects was low and increased in the last transects away from the settlements. Student t-test showed significant differences between the proximal areas (1.154 ± 0.368 seedlings per 0.04 ha) and the distant areas (1.875 ± 1.178 seedlings per 0.04 ha) of settlements at p= 0.0002.

Keywords: Anthropogenic disturbance, Forest structure, Species composition, Regeneration, Western Ghats of India

Introduction

Deforestation is a global phenomenon resulting in loss of 15 million hectares of forests every year. Over the period of 1980-1990, deforestation reached 8.2 per cent of total forest area in Asia, 6.1 per cent in Latin America and 4.8 per cent in Africa. It mainly takes place in the developing countries, particularly in tropical areas due to the population pressure. With an increased population, there would be more families in search of land for agriculture or looking for fuelwood or timber. Thus, more deforestation and higher pressures to degrade forests make intuitive sense [1]**.** It is estimated that at the current rate of deforestation and degradation, about 20 per cent of the tropical forest by the year 2020 and more than 50 per cent of the same by the year 2024 is likely to be lost [2]. India has 64 Mha under forests of which 72 per cent are tropical moist deciduous, dry deciduous and wet evergreen forest [3]. The later part of the 20^{th} century had witnessed an alarming rate of deforestation of the tropical forests of the world and its impact on biodiversity [4].

To estimate the impact of human interference, the hypothesis which is assumed that forest sites proximal to human settlements are relatively more disturbed than sites distant from the settlements. This assumption depends on the fact that cost of harvesting forest resources increases with distance from the settlement areas [5].

Fire and indiscriminate grazing are the most important factors affecting the natural regeneration in the forest [6] Human induced disturbances, mainly e.g. grazing activities or tree harvesting, strongly influence the regeneration success of woody species and in turn determine the vegetation structure and composition of these forests [7]. Organized smuggling, encroachment and illicit removals by the local villagers living in and around forests are serious problems [8]. India has the largest livestock population in the world. The population was 292 million in 1951 and increased to 429.9, 445 and 500 million in the years 1987, 1990 and 2000 respectively. It is estimated that by 2010 it would exceed 5 thousand million, and of these, 270 million cattle graze on forestland leading to its degradation [9].

[10] reported that the palatable herbs and shrubs are increasingly being replaced by unpalatable species in the open forest. [11] ; [12] pointed out that excessive grazing by cattle leads to the lack of regeneration in certain forests of Kashmir and conversion of forest area into barren ground. [13]; [14] reported that the frequent fires have profound implications on the forest structure, composition and functioning. The human occupation in the Western Ghats is ancient but large-scale deforestation and destruction of forests is a more recent phenomenon [15]; [16]. In the present study an attempt has been made to estimate the impact of anthropogenic activities on forest structure, species composition and regeneration in the proximal and distant areas of the settlements.

Material and methods

Study site

The present study was carried out in moist deciduous forests of Thithimathi (75º 25'- 76º 14´ E and 12º 15´- 12º 45´N) of Virajpet taluk, Coorg district (Fig. 1). These forests have a combination of forested ecosystems and villages. A preliminary reconnaissance survey was done to identify the different sites in the study area. Six study areas were selected in the buffer zone of moist deciduous forest. From the fringe of each hamlet (disturbed area), five transects of 100 m X 4 m were laid towards the reserve forest with an interval of 300 m covering a total distance of 2 Km deep in the forest(less disturbed area). This study would imply the comparison between the first transect in six hamlets as more disturbed area with the last transect as less disturbed area. In six hamlets, first transects were grouped together as more disturbed area, likewise second, third, fourth and fifth transect as less disturbed areas. In these sites, different characteristics such as distance from the settlement area to the forest, sign of disturbance like formation of footpath, presence of cut stumps or broken stems and animal grazing were considered. It is assumed that forest site which is close to the settlement is relatively more disturbed than the sites which are away from the settlement.

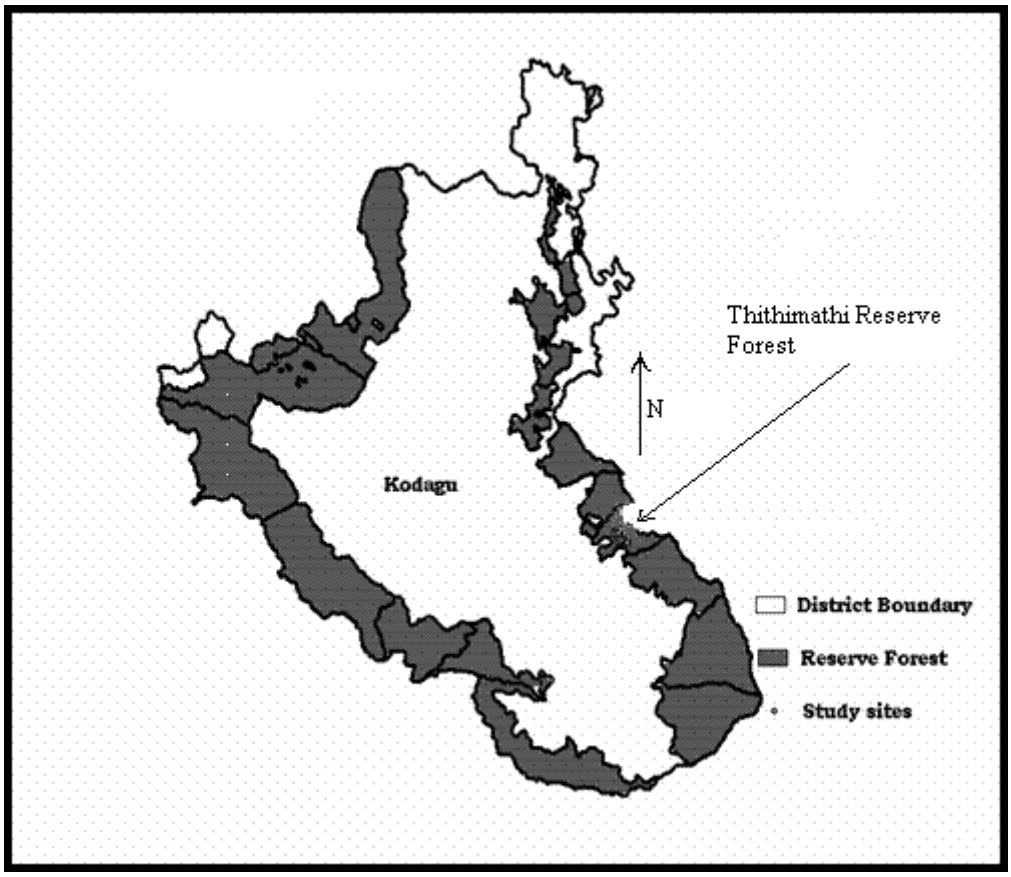

Figure 1: Map of Thithimathi (study area) Central Western Ghats of India.

Data collection

Systematic sampling technique was adopted in the study area, total of 30 transects were laid (each transect of 100m × 4m dimension). Within the area of each transect (400 m²), the species were enumerated to estimate the species richness and diversity. All individual trees above 0.30 m girth at the breast height of 1.37 m above the ground level were enumerated by using a measuring tape. The regeneration plot of 2 m into 2 m dimensions was laid out at 0 m, 25 m, 50 m, 75 m and 100 m distance along the transect to be in total 150 plot. In regeneration plot, all plant species below 0.30 m gbh were considered as regenerative seedlings and enumerated separately into regeneration classes i.e., I < 40 cm height, II between 40-100 cm height, 100 m height < III < 10 cm gbh, and 100 cm height < IV 10 - 30 cm gbh

In each regeneration plot, the details about regeneration classes were taken and plants were identified using field keys of Flora of Coorg [17, 18] and Flora of Karnataka ([19, 20]. Disturbance factors were recorded in transects and scores were given based on the observation on the amount of disturbance. Four levels of disturbance were given to each parameter namely absent, low, medium and high with values of 1 to 4 for each level. The value of 1 was considered as the absence of disturbance, whereas the value of 4 was considered as severe disturbance of the biotic factors such as grazing, domestic animal's dung (DAD), wild animal's dung (WAD), cut stumps, logging, litter collection, soil removal, fire, footpath formation and weeds. However, the scale used for canopy opening was based on the amount of light which penetrate the canopy and reach the ground of the forest or by ground area which has been covered by the canopy. Thus, five ranges were given for the canopy opening i.e., (0-20 %, 20-40 %, 40-60 %, 60-80 %, 80-100%). The range of 0-20 % is considered as less canopy opening (less disturbance) and 80-100 % as more canopy opening (high disturbance). All the disturbance parameters were taken from the sampled areas.

Data analysis

Shannon's diversity index [21] is a measure of the average degree of uncertainty in predicting to what the species individuals chosen at random from a collection of S species and N individuals belong. It is calculated from the following formula:

$$H' = -\sum_{i=1}^{s}[(ni/N)^{*} \ln (ni/N)] \quad (1)$$

where n_i is the number of individuals belonging to the i^{th} species and N is the total number of individuals in the sample and S the number of species. The number of individuals, density and basal area were estimated in the six hamlets (Sites) in the proximal and distance of the forest to the settlements as the following:

$$Basal\ area = g^2/4\pi \quad (2)$$

where g is girth at breast height (1.37 m)

The collected data were subjected to analysis by assessing relative frequency, relative density and relative dominance. Based on these parameters, the important value index (IVI) at species level was calculated following the method of Curtis and Mcintosh [22, 23]. IVI gives the importance of species in the community by assigning rank to individual species. The IVI can be calculated as follows:

$$Density\ (ni): Number\ of\ indivuals\ of\ the\ species\ A \quad (3)$$

$$Relative\ density\ (RD) = \frac{Number\ of\ individuals\ of\ species\ A}{Total\ number\ of\ individuals\ of\ all\ species} \times 100 \quad (4)$$

$$Relative\ dominance\ (RD) = \frac{Total\ basal\ area\ of\ species\ A}{Total\ basal\ area\ of\ all\ species} \times 100 \quad (5)$$

$$Frequency\ (fi) = \frac{Number\ of\ transects\ in\ which\ species\ A\ occurs}{Total\ number\ of\ transects\ sampled} \times 100 \quad (6)$$

$$Relative\ freqqency\ (Rf) = \frac{Frequency\ value\ for\ species\ A}{Sum\ of\ frequency\ value\ of\ all\ species} \times 100 \quad (7)$$

$$IVI_{growing\ stock} = Relative\ density(RD) + Relattvedominance(Rd) + Relative\ frequency(Rf) \times 100 \quad (8)$$

According to Earl [24], the average value index (AVI) was adopted to categorize the impact of disturbance parameters on the composition and structure of the forest. The outcome of the analyzed data grouped the disturbance parameters of growing stock into major, moderate and minor disturbance categories having the AVI value ≥ 1.55 , 1-1.54 and ≤1 respectively. ANOVA and Student t-test were used for testing the significance of these parameters between transects proximal and distant to the settlement by using GENSTAT (4.24DE) software and MW Excel. The cumulative disturbance index (CDI) adopted to estimate the correlation between disturbance parameters and regeneration, number ofindividuals, basal area and density [25].

Results

Species richness and diversity

The comparison between proximal and distant areas of the forest to the settlements in terms of species richness and Shannon's diversity index is presented in Table 1. The species richness, Shannon's index, number of individuals, density and basal area were less in the proximal areas with value of 22 species, 2.75, 74 tree /ha, 308 stem/ha and 4.92 m^2 /ha as compared to distant areas 24 species, 2.79, 129 tree/ha, 537 stem/ha and 6.8 m^2 /ha respectively (Table. 1and 2). There were no significant differences in number of individuals and basal area between the proximal areas (2.355 ±1.624 per 0.04 ha) (0.103 ±0.131 m^2 per ha) and distant areas (2.745± 3.00 trees per 0.04 ha) and (0.086 ± 0.130 m2 per 0.25 ha) at p-value = 0.452 and p-value= 0.331 respectively. The disturbance alters the density per hectare of different components such as trees, shrubs and herbs resulting of higher density of herbs, shrubs and trees Fig. 2.

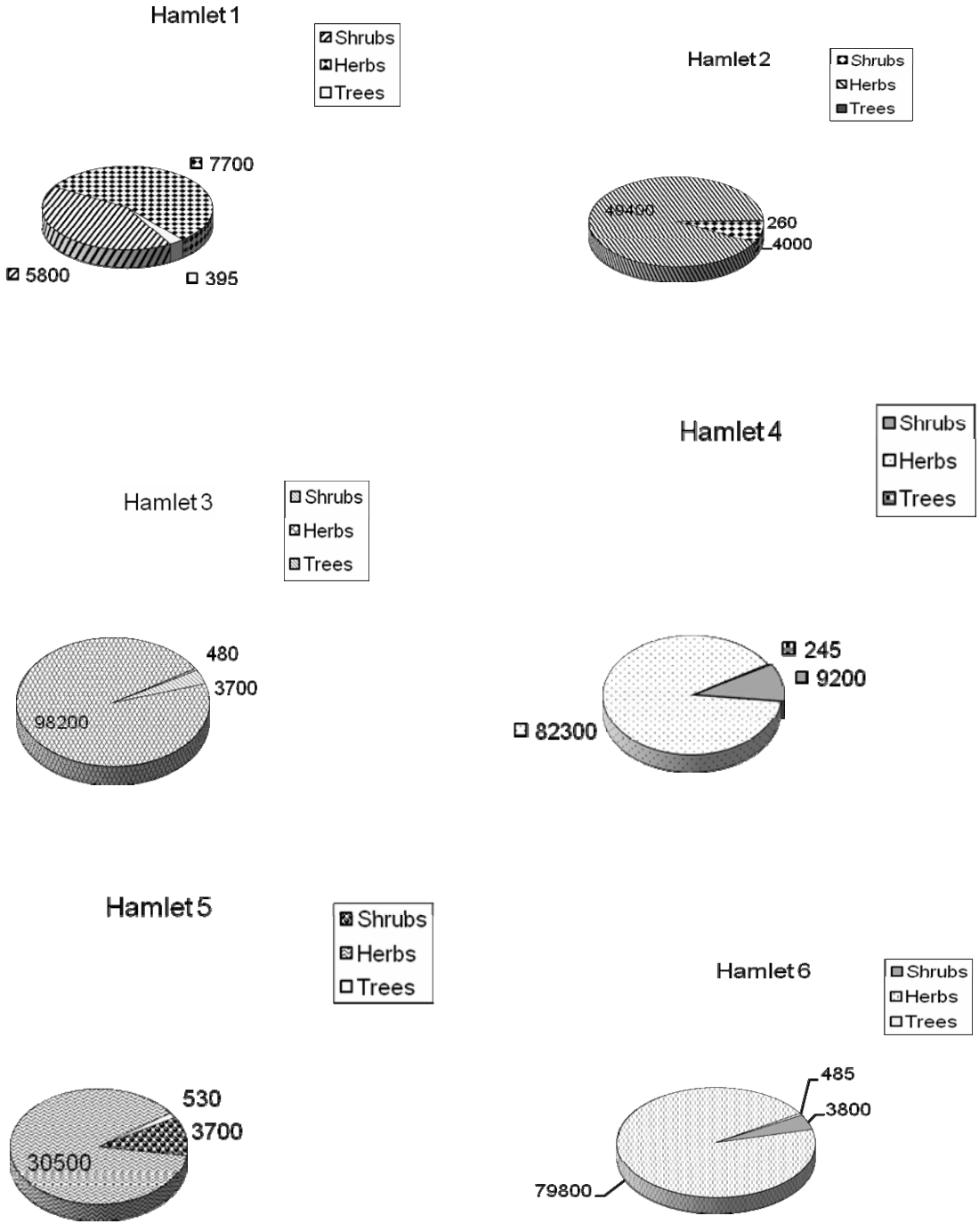

Figure 2: density /ha of herbs, shrubs and trees.

Table 1: Species richness and Shannon's diversity index for growing stock and regeneration in the proximal and distant areas to the settlements.

Transect	Species richness		Shannon's diversity index	
	Growing stock	Regeneration	Growing stock	Regeneration
1 [a]	22	19	2.75	2.73
2	23	20	2.69	2.80
3	23	23	2.74	2.89
4	23	24	2.68	2.74
5 [b]	24	27	2.77	2.95
Total	39	45		

[a] Transect 1 was close to the settlements
[b] Transect 5 was distant to the settlements

Table 2: Total number of individuals, density and basal area for growing stock and regeneration in the proximal and distant areas to the settlements.
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Transect	**Growing stock**			**Regeneration**	
	Total no of individuals observed	**Density /ha**	**Basal area m^2/ha**	**Total number of individuals observed**	**Density /ha**
1 [a]	74	308	4.92	25	2083
2	78	325	5.31	49	4083
3	87	362	6.70	64	5333
4	111	462	6.53	82	6833
5 [b]	129	537	6.80	90	7500

[a] Transect 1 was close to the settlements
[b] Transect 5 was distant to the settlements

Table 3 shows five dominant species in different hamlets based on IVI. In the first hamlet, *Vitex altíssima* topped the list with IVI value of 69.04. In third and fourth hamlet, the dominant species were *Lagerstroemia microcarpa* (51.02) and *Terminalia crenulata* (42.02). Whereas, *Tectona grandis* topped the list of five species in the second, fifth and sixth hamlets with IVI value of 66.77, 97.59 and 69.58, respectively. *Tectona grandis* was also found in the third and fourth hamlets having IVI value of 13.40 and 38.75, respectively. *Eucalyptus spp* was one of the dominant species in the fifth hamlet with IVI value of 35.55 and it was not found a dominant species in any other hamlets. The disturbance parameters were characterized with respect to the AVI into three categories viz; major disturbance i.e., canopy opening, cut stumps, weeds and grazing with AVI ≥ 1.55, moderate disturbance i.e, lopping, WAD, footpath and DAD with an average of 1.0 to 1.54 and minor disturbance such as litter collection, fire and soil removal with an average ≤ 1.0 as shown in Table 4, Fig. 3, Fig. 4.

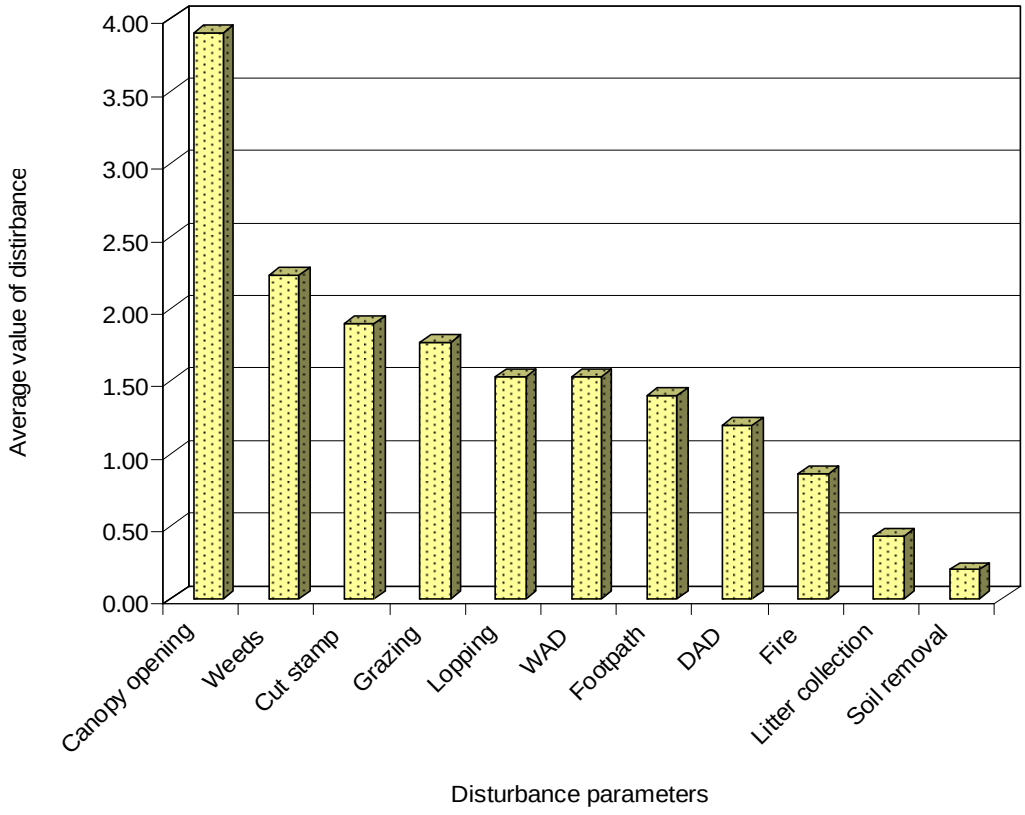

Figure 3: Average value index of disturbance parameters AVI.

Figure 3: Five dominant trees in the study area based on IVI in six hamlets.

Species	Hamlet 1		Hamlet 2		Hamlet 3		Hamlet 4		Hamlet 5		Hamlet 6	
	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank
Vitex altissima	69.04	1	-	-	-	-	-	-	-	-	-	-
Terminalia crenulata	45.31	2			21.09	4	42.02	1	46.49	2	17.89	3
Terminalia paniculata	26.00	3	31.11	2	26.88	2	-	-	-	-	17.58	5
Pterocarpus marsupium	21.01	4	-	-	26.27	3	-	-	-	-	-	-
Lagerstroemia microcarpa	13.16	5	15.48	4	51.02	1	29.19	3	-	-	21.42	2
Tectona grandis	-	-	66.77	1			38.75	2	97.59	1	69.58	1
Terminalia belerica	-	-	27.59	3	-	-	-	-	-	-	-	-
Dillenia pentagyna	-	-	9.96	5	-	-	22.13	4	-	-	-	-
Anogeisus latifolia	-	-	-	-	-	-	-	-	25.07	4	-	-
Dalbergia latifolia	-	-	-	-	-	-	-	-	-	-	17.78	4
Dendrocalamus strictus	-	-	-	-	18.87	5	-	-	-	-	-	-
Butea monosperma	-	-	-	-	-	-	21.05	5	19.07	5	-	-

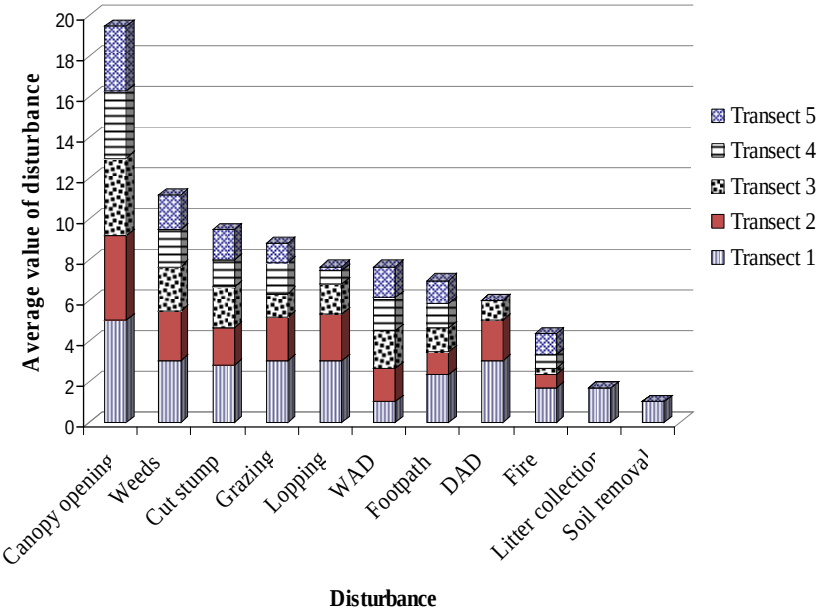

Figure 4: Average disturbance parameters in proximal and distant transects to settlements.

Table 4: Average values of disturbance of different parameters in the areas close and distant from the settlements.

Disturbance parameters		Transect ⇨ Distant from Settlements				
		1	2	3	4	5
1	Canopy opening	5.0	4.2	3.8	3.3	3.2
2	Weeds	3.0	2.5	2.2	1.8	1.7
3	Cut stump	2.8	1.8	2.0	1.3	1.5
4	Grazing	3.0	2.2	1.2	1.5	1.0
5	Lopping	3.0	2.3	1.5	0.7	0.2
6	WAD	1.0	1.7	1.8	1.7	1.5
7	Footpath	2.3	1.2	1.2	1.2	1.2
8	DAD	3.0	2.0	1.0	0.0	0.0
9	Fire	1.7	0.7	0.3	0.7	1.0
10	Litter collection	1.7	0.3	0.0	0.2	0.0
11	Soil removal	1.0	0.0	0.0	0.0	0.0
	CDI	27.5	18.9	15	12.4	11.3

Notes:
Major disturbance with average ≥ 1.55
Moderate disturbance 1-1.54
Minor disturbance ≤1
CDI cumulative disturbance inde

Major disturbance

The value of canopy opening disturbance was very high in the proximal areas with AVI of 5.0, whereas the impact gradually decreased in the distant areas to AVI of 3.2. Therefore, significant difference between the proximal and the distant areas was observed (Table 5). In the proximal areas, the abundance of invasive weeds was high with AVI of 3.0, whereas in the distant areas AVI was 1.7 and the decrease was not significant (Table 4). The average disturbance value of cut stumps was high in the proximal areas with AVI of 2.8 which decreased as moving away from the settlements with AVI of 1.5 and showed significant difference between proximal and distant areas. The grazing incidence between proximal and distant areas from the settlements showed significant differences. In the first transects, grazing was very high with AVI of 3.0, whereas in the last transects was less affected with AVI of 1.0.

Table 5: ANOVA test of disturbance parameters of six hamlets.

	Parameters of disturbance										
Transects	Lopping	Cut stumps	Collection of litter	Soil removal	Grazing	Fire	Weeds	Footpath	DAD	WAD	canopy opening
Transect 1[a]	1.63*	1.68*	0.28*	0.25*	0.57*	0.38	0.69	0.30	0.58*	0.30	0.78*
Transect 2	1.40	1.33	0.08	0.10	0.49	0.20	0.52	0.33	0.05	0.42	0.71
Transect 3	1.33	1.38	0.05	0.00	0.31	0.08	0.54	0.33	0.28	0.45	0.68
Transect 4	1.18	1.04	0.10	0.00	0.38	0.20	0.51	0.33	0.00	0.40	0.63
Transect 5[b]	0.93	1.09	0.05	0.05	0.40	0.26	0.52	0.31	0.05	0.34	0.62
L.S.D	0.47	0.47	0.19	0.18	0.16	0.20	0.16	0.09	0.11	0.17	0.04

*Significant @ 5%

[a] Transect 1 was more disturbed area

[b] Transect 5 was less disturbed area

L.S.D less significance differences

Moderate disturbance parameters

The lopping incidence and DAD showed significant difference between the proximal and the distant areas with AVI of 3.0, 3.0 and 0.2, 0.0 respectively (Table 4and 5). The abundance of WAD (Elephants) and footpath formation were not significant in the proximal and distant areas with AVI of 1.0, 2.3 and 1.5, 1.2 respectively.

Minor disturbance parameters

The litter collection and soil removal were significantly different with AVI of 1.7, 1.0 in the proximal areas and 0.0, 0.0 in the distant areas respectively (Table 4). The AVI of fire incidence in the first transects was 1.7 and 1.0 in the last transects and the differences was non-significance (Table 5). The strong positive correlations in density and basal area between the proximal and distant areas are 0.70 and 0.97, respectively.

Regeneration study

Table 1 revealed that the species richness and Shannon's diversity index of regeneration were 19 species and 2.73 in the proximal areas and increased into 27 species and 2.93 as the distance increased from the settlements respectively. The total number of regenerated seedlings and density were 25 seedlings and 2083 stems/ha in the first transects and 90 and 7500 stems/ ha in the last transects respectively (Table 2).The student t-test showed significant difference in the number of seedlings between the proximal areas (1.154 ± 0.368 seedlings per 0.04 ha) and the distant areas (1.875 ± 1.178 seedlings per 0.04 ha) at $p = 0.0002$.

Fig. 5 shows strong correlation between the CDI of a site and the regeneration density of population. The increased level of CDI resulted in the decreased regeneration status spite the association was $R^2 = 0.7755$. The trend line showed higher density of regenerating individuals in low and medium level of CDI with AVI of 10 and 12, and decreased drastically with increase the value of CDI more than 12. The medium level of disturbance showed good amount of regenerating individuals. The distribution of regeneration classes followed the reverse J- shaped curve Fig 6. The first hamlet showed that there were similarities in I and II class, whereas the other hamlets showed an occurrence of more number of I class.

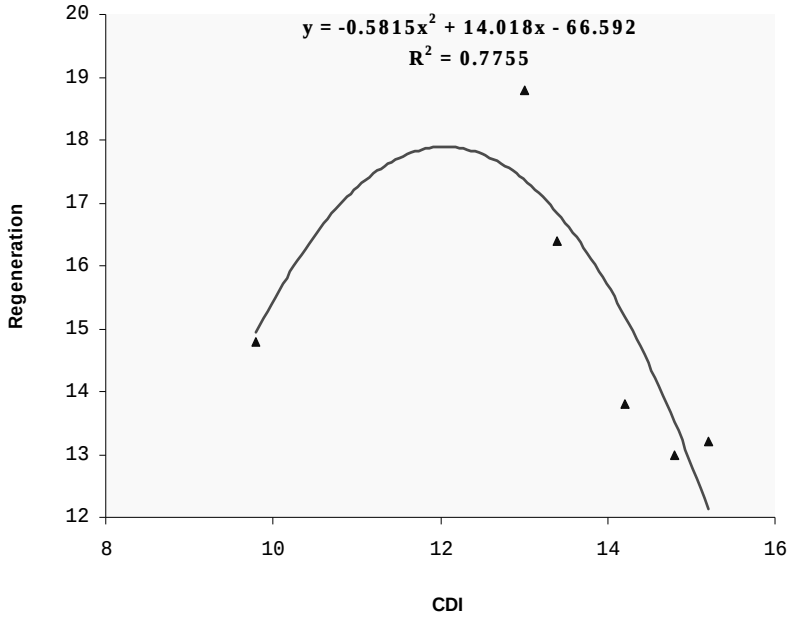

Figure 5: Relation between regeneration and cumulative disturbance index.

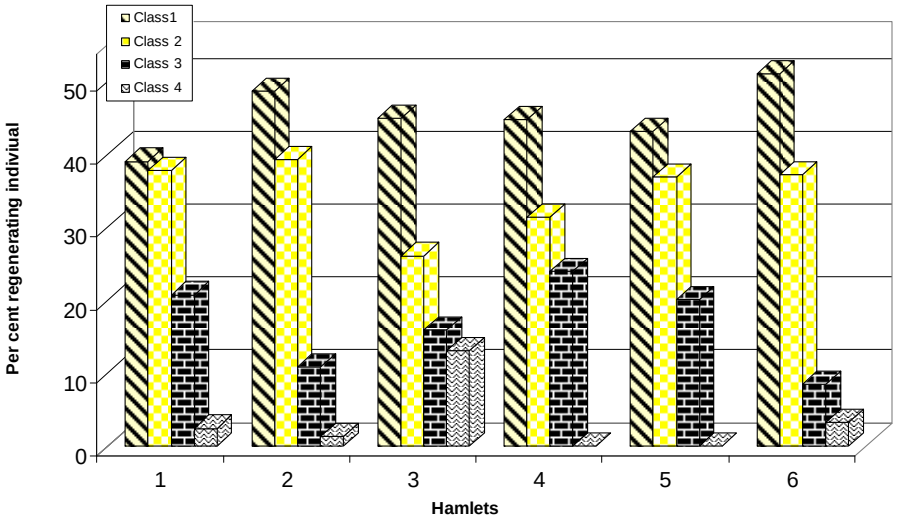

Figure 6: Distribution of regeneration classes in six hamlets.

Discussion

Species richness and diversity

The species richness and Shannon's diversity index were 22, 2.75 in the proximal areas and increased up to 24, 2.77 respectively in the distant areas (Table 1). This is may be attributed to the fact that disturbance always increases the species richness by altering the species composition and inducing secondary and invasion species to occupy the site. [26] and; [27] reported that the total number of species and Shannon's index were more at the distant sites as compared to proximal sites. Kumar and Shahabuddin [28] found that biomass extraction caused significant changes in forest vegetation structure and species composition in the tree layer.

The number of individual trees in the different transects varied considerably in almost all transects from proximal to distant where disturbance was recorded (Table 2). The number of individuals gradually increased from transects 1 to 5 i.e., a clear indication of the impact of distance factor on disturbance levels. The forest area which is the proximal areas to the hamlets had more disturbances resulting in reduction in the number of trees. The number of individual trees was 74 in the proximal areas and 129 in distant areas. This increase may be attributed to the decrease in the biomass extraction in the form of grazing, fuelwood collection and lopping (Table 4)**. [**29] reported that biomass extraction in the form of grazing, fuelwood collection and non-timber forest products is the most widespread pressure in forests in the developing countries where rural population depend significantly on these activities for household and livelihood needs. Similarly, Bhuyan [30] reported that reduction in stem density of wood plants was recorded as a result of anthropogenic disturbance in several other tropical forest areas.

The density and basal area in the proximal areas were 308 stems/ha and 4.92 m^2 /ha, whereas the density and basal area in the distant areas were 537 stems/ha and 6.80 m^2 /ha, respectively (Table. 2). These variations are due to the anthropogenic

pressure in different form of disturbance such as NTFPs and fuelwood collection, lopping, grazing *etc.* But, the pressure on the forest decreased as distant away from the settlements due to more effort and time required to collect the biomass. Highly disturbed zone had 200 trees /ha, which increased abruptly to around 300 trees/ha in moist deciduous forest and more than 1200 trees/ ha in evergreen forest at the different level of disturbance [27]. In blue oak savanna ecosystems in California, non-native plant cover and richness was higher in areas that were heavily grazed by cattle compared to ungrazed plots [31]. The present study revealed that the disturbance altered the proportion density of the forest components i.e., herbs, shrubs and trees (Fig. 2). The area occupied by herbs and shrubs was high compared to the area of occupancy of trees in all the hamlets.

The first hamlet was dominated by *Vitex altissima* with the highest value of IVI followed by *Terminalia crenulata.* Whereas, *Tectona grandis* dominated in hamlets 2, 5, 6 followed by *Terminalia paniculata, Terminalia crenulata and Lagerstroemia microcarpa* respectively. Hamlet 3 was dominated by *Lagerstroemia microcarpa* followed by *Terminalia paniculata*. In hamlet 4, *Terminalia crenulata*, was the dominant species followed by *Tectona grandis* (Table.4). The dominance of these species could be attributed to the adaptation of these species to disturbance and open canopy areas.

Major disturbance parameters.

The forest structure, composition and regeneration were affected by major disturbance factors i.e., canopy opening, cut stumps, weeds and grazing based on the AVI (Table 4 and Fig. 3). However, the disturbance index showed that there was high disturbance in all the hamlets due to the similarity in the vegetation type (moist deciduous forest) as well as high anthropogenic pressure. The statistical analysis showed that the disturbance of canopy opening, cut stumps, weeds and grazing varied significantly between proximal and distant areas from the settlement (Table. 5). This could be attributed to the amount of biomass extracted by people through illicit activities such as severe lopping, cutting and over grazing in the proximal areas. [32]; [26] and [5] explained the ecological consequences of human dependence on the forest and deduced that forest sites proximal to human settlements were relatively more disturbed than the sites distant from the settlements, due to the opportunity cost of harvesting. About 154 species of medicinal plants were recorded as rare, endangered and threatened due to human pressures in south India [33]. [11] and [12] pointed out that excessive grazing by cattle leads to the lack of regeneration in certain forests of Kashmir and conversion of forest area in to barren ground.

Moderate disturbance parameters

The vegetation structure and composition showed moderate response to the lopping, WAD, footpath formation and DAD (Table 4 and Fig. 3). In proximal and distant areas, these parameters had a decisive impact in proximal transect than in distant transect from the settlements. It is inferred that the dependency of energy sources totally comes from the forest. Our results are consistent with findings of Sagar [34],

who observed a shift from clumped to uniform dispersion patterns associated with a change from higher to lower stem density.

Minor disturbance parameters.

Fire, soil removal and litter collection were minor disturbance parameters with respect to the AVI (Table 4 and Fig. 3) .The study areas showed more or less similarity in their susceptible to these parameters which occurred occasionally such as litter collection. In transect proximal to the settlement areas, the impact was more because these disturbances mainly happened near the settlement as a consequence of the human activities which their impact decreased by increasing the distance. This confirms the fact that cost of collecting the soil and litter will be less in the nearest area to the settlement. Further CDI showed strong correlation with growing stock in the proximal and distant areas to the settlements (Table 4). [35] found that population at the proximal sites (most disturbed) were more affected than those of distant sites (least disturbed).

Regeneration study

The regeneration was affected by the anthropogenic pressure along transects between the proximal and distant areas (Table 4). This is because of the higher values for the entire disturbance parameters were noticed in the proximal areas and the lower disturbance parameters were observed in the distant areas. Species richness in the proximal and distant areas showed that the number of species per unit area increased with increasing the distance from the settlements (Table 1). The disturbance was high in the first transects and decreased by increasing the distance for all disturbance parameters. These findings are inline with the results supported by Shaankar [35]. They were of the opinion that the anthropogenic pressures especially harvesting of NTFPs, had lead to the poor regeneration of these species. The disturbance levels increased the species richness as reported by [36]. The total number of seedlings and density in the proximal area decreased as compared to the distant area from the settlements (Table 2). It could be attributed to the very high value of CDI (27.5) in the first transects and the least CDI (11.3) in the last transects (Table 4). Anthropogenic pressures including harvesting of the fruits of *Phyllanthus emblica* had significantly reduced the recruitment and regeneration of the species at BRT hills, and the seedling vigour decreased from the least disturbed to the highly disturbed populations as reported by [37]

CDI showed a negative correlation with the regeneration density as shown in Fig. 5. Generally, the vegetation needs a mild disturbance to induce regeneration like canopy opening and grazing. In this study, when the cumulative average disturbance parameter was correlated with the density of regeneration, it was found that the regeneration increased within the mild disturbance. However, increasing the disturbance caused negative impact on the regeneration. [38] Found that the overall stem density (i.e., density of advanced regeneration, poles and adult trees) was higher in the moderately disturbed forests than in either the least or heavily disturbed forests. [25] Reported that an increased level of CDI resulted in decreasing the regeneration status showing higher density of regeneration in low and medium level of CDI and

drastic reduction with higher CDI. The medium level of disturbance showed a good amount of regeneration.

In the 6 hamlets of moist deciduous forest, distribution of regenerated size class seedlings showed a reverse J-shaped curve (Fig. 6), revealing the normal distribution classes of regeneration in different hamlets in the study sites. [39] reported that a large number of regenerated species in class I was attributed to the effect of grazing and fire on the regeneration. [36] found that there was a significant decrease in the small size seedlings (<10 cm dbh) individuals of NTFPs species due to disturbance.

Conclusion

This work has succeeded in developing the forest cumulative disturbance parameters using average model, quantifying the major changes in forest loss and regeneration for both proximal and distant areas of the settlements in Thithimathi, Western Ghats, India, and ultimately creating a comparison profile of forest change due to the disturbance. The results indicated a slight difference in species richness between the proximal and distant areas. The density and basal area were less in the proximal areas as compared to the distant areas. Canopy opening was the highest disturbance parameter whereas soil removal was the least disturbance parameter of forest. Increased level of CDI resulted in the decreased regeneration status with an associated value of (R^2= 0.7755).

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